SERMA TECHNOLOGIES

HAMAMATSU PHOTODIODES (DPD-S8576)
EVALUATION N°4
20 DPD's CYCLED BY HAMAMATSU
REPORT E02P1443 - NOVEMBER, 2002

This evaluation was performed for :

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1. INTRODUCTION

1.1 Purpose.

The evaluations n°1 and n°2 (DR1, DR2) and the failure analysis (DR3) performed by SERMA Technologies on DPDs from lot 1G showed delaminations and cracks on the epoxy resin above the optical zones of the DPDs with lost of electrical contact.

The thermal cycles performed by NRL and HAMAMATSU on DPD'S do not show any lost of electrical contact. The DPDs used by HAMAMATSU were baked out 5 hours at 150°C before the thermal cycles.

Notice: This temperature is higher than Tg temperature of epoxy resin.

The goal of this new evaluation is to perform, on two lots of DPDs already baked out at 150°C and thermally cycled by HAMAMATSU, comparable controls to the evaluation n°3, and also to use the same set of tools as evaluations 1, 2 and 3.

We received two different manufacturing lots, 10 parts from a not identified lot and 10 parts from lot 2D.

1.2 Procedures & references.

1.2.1 References

DR1	Hamamatsu photodiodes (DPD-S8576) (evaluation n°1)	SERMA E01P1435
DR2	Hamamatsu photodiodes (DPD-S8576) (evaluation. n°2	SERMA E02P0638
DR3	Failure analysis	SERMA E02P1100
DR4	Evaluation technologique n°3 des DPDs (S8576) Comparaison lot 1G et 2B	SEDI-GLAT-Y-05-213PC
DR5	Evaluation technologique n°4 des DPDs (S8576) Cyclées par Hamamatsu	SEDI-GLAT-Y-05-220PB

1.2.2 Procedures

PLAB009	Traitement d'une analyse, SERMA internal procedure, 12/03/2001
ILAB033	Analyse par microscopie acoustique, SERMA internal procedure, 18/09/2001
JEDEC J-STD035	Acoustic microscopy for non hermetic encapsulated electronics components

2. CONCLUSION

- No major defects were detected on the 2 lots.
- There is no significant difference with previous analysis (DR4), but no crack at ceramic corner was observed on these lots.
- The initial visual inspection performed by SERMA Technologies correlate the previous observation performed by HAMAMATSU on lot H2 (2D). (Reference : email from Andrew Allen to Neil Johnson on august 29th).
- The epoxy resin thickness seems to be different than the previous lots (1G and 2B), the acoustic observation shows an irregular epoxy layer.
- The weight of these lots is lower than the previous lots (see analysis DR1 & DR2), so the epoxy resin weight is also lower.
- There is no major difference on the DPDs before and after the 40 thermal cycles performed on the 5 parts of lot H2 (2D).
- All the parts from the 2 lots were electrically functional from 60°C to –30°C after the 60 thermal cycles performed
- No delamination was observed at epoxy/die interface unlike the previous analysis (DR1 and DR2)
- No defect was detected on the wire bonding on two samples from lots 2D at S.E.M observation.

Actions :

- An additional analysis has to be done by the CEA to verify the weight and the thickness of the epoxy resin.
- An additional analysis was performed to evaluate the epoxy resin characteristic of each lot (see report SERMA Technologies E02P1503).

3. EVALUATION PLAN

The evaluation was oriented to the analysis of the physical performance of epoxy resin used in the DPDs according to the thermal cycles number.

3.1 Components identification

The parts were received at SERMA Technologies in 2 different dry-packing, each of them was clearly identified. There was one plastic box inside the dry packing containing 10 DPDs plugged on pink antistatic foam on two lines of 5, another stickers were also inside the box to identify the DPDs. Photos were taken at each opening step (see photos I1 to I3 in annex).

Dry packing bag identification	Boxes identification (inside)	Lot Nbr.
S8576 TC (1) -30 to +60°C, 5°C / min, 100c completed -30 to +60°C, 7.5°C / min, 100c completed	**S8576 TC (1) (top)** -30 to +60°C, 5°C / min, 100c completed -30 to +60°C, 7.5°C / min, 100c completed	**
S8576 TC (2) -30 to +60°C, 5°C / min, 100c completed	**S8576 TC (2) (top)** -30 to +60°C, 5°C / min, 100c completed N° 737-741 (bottom) Backing 150°C, 5h N° 742-746 Backing 150°C, 5h 85°C x 60% RH, 10h	2D

** This lot was not identified, the DPDs were numbered from 1 to 10, we presume that the 1 to 5 were submitted to thermal cycles with 5C / min and the 6 to 10 with 7.5°C / min.

The two bags of DPDs were identified in two groups and three lots :

Bags	Groups	Lot Nbr.	DPDs Nbr.
H1 : S8576 TC (1)	**C1:** cycles at 5°C / min **C2:** cycles at 7.5°C / min	H1C1 H1C2	S/N 1 to 5 S/N 6 to 10
H2 : S8576 TC (2) cycles at 5°C / min	**C1:** Baking only **C2:** Baking and T&H	H2C1 H2C2	S/N 737 - 741 S/N 742 - 746

3.2 Tests description

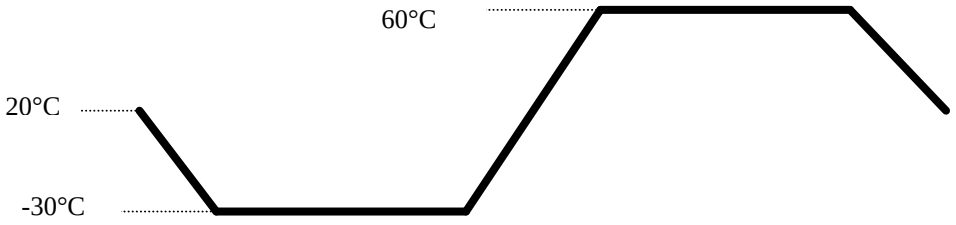
The DPDs were submitted to the following tests :

- For all the DPDs
  - Electrical measurement at ambient temperature (electrical contact verification)
  - Visual inspection of epoxy resin
  - Weighing of DPDs
  - Acoustic microscopy to observe potential delamination
  - Weighing of DPDs
  - Bake out : 4 hours at 55°C
  - Electrical measurement from 60°C to –30°C (electrical contact verification)
  - S.E.M. wire bonding observation on some suspicious parts

- For 5 DPDs of lot 2D (H2)
  - Bake out of 24 hours at 85°C
  - 40 thermal cycles –30°C / 60°C with 2°C/mn
  - Electrical measurement from 60°C to –30°C (electrical contact verification)
  - Acoustic microscopy to observe potential delamination

3.3 Thermal cycle description

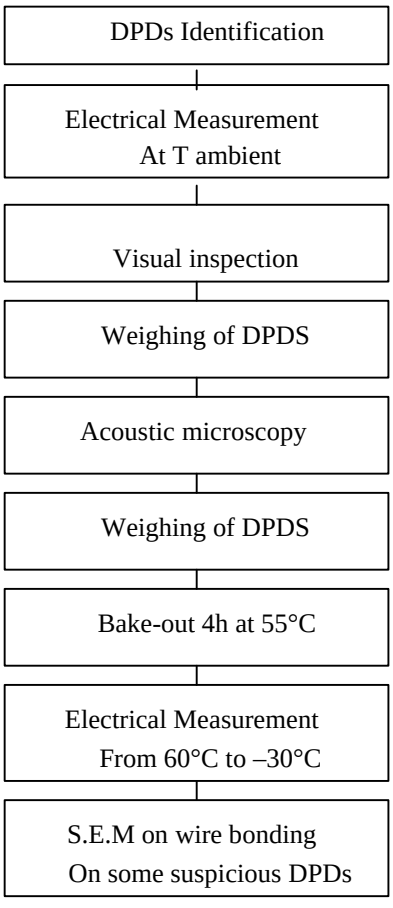
A thermal cycle is defined as follows:



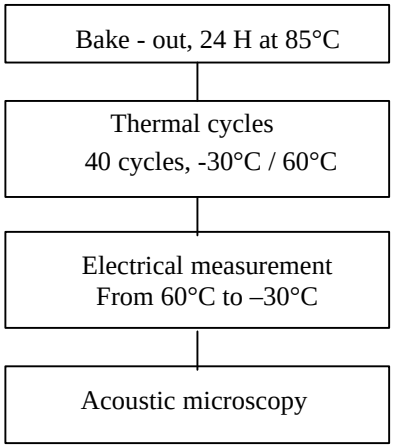
Dwell time at each temperature (-30°C or 60°C):	30 mn
Slope of temperature for transition:	2°C / mn
Cycle time duration:	150 mn

3.4 Evaluation flow chart

For all Parts (20 DPDs)



For 5 DPDs from lot 2D



4. VISUAL INSPECTION

4.1 Results synthesis

All the parts were observed at reception and after the 40 thermal cycles for 5 of them.

Only the defects or their evolution were documented all along the observations performed. No photography was taken in case of defect stability.

The DPDs serial numbers and the figures numbers are detailed on the 3 next pages for each lot. Examples of defects (figures) are given in annex.

- LOT H1

No crack was observed in the epoxy resin.

Delaminations (“peeling-off”) between epoxy and ceramic on 9 parts out of 10 and between epoxy and bonding area on 2 parts out of 10 were observed.

- LOT H2 (2D)

No crack was observed in the epoxy resin.

Delaminations (“peeling-off”) between epoxy and ceramic on 8 parts out of 10 and between epoxy and bonding area on one part were observed.

On the 5 parts submitted to the 40 additional thermal cycles, 3 out of 5 show a small increase of delaminations between epoxy and ceramic, and 4 out of 5 between epoxy and bonding area .No evolution was observed on one part.

There is no significant difference between the sub-lot H2C1 and H2C2 at initial and after 40 cycles.

4.2 Lot H1 results

		SERIAL NUMBERS									
		1	2	3	4	5	6	7	8	9	10
		H1C1					H1C2				
T_0	Cracks (ceramic corner)										
	Cracks (bonding area)										
	Delamination Epoxy/ceramic	X	X	X Fig 1	X	X		X	X	X Fig 1	X
	Delamination Epoxy/bonding area						X	X Fig 1			

4.3 Lot H2 results

		SERIAL NUMBERS									
		737	738	739	740	741	742	743	744	745	746
		H2C1					H2C2				
T_0	Cracks (ceramic corner)										
	Cracks (bonding area)										
	Delamination Epoxy/ceramic	X	X	X		X	X	X Fig 2	X		X Fig 2
	Delamination Epoxy/bonding area									X Fig 2	

4.4 Lot H2 results (after 40 thermal cycles)

		SERIAL NUMBERS									
			738			741	742		744		746
		H2C1					H2C2				
T_1	Cracks (ceramic corner)										
	Cracks (bonding area)										
	Delamination Epoxy/ceramic		X(+)				X(+) Fig 3		X (=)		X(+) Fig 3
	Delamination Epoxy/bonding area		X			X	X Fig 3				X

5. ACOUSTIC MICROSCOPY RESULTS

5.1 Notice

Principle:
The image is formed by the component scanning by an acoustic transducer, the reflected part of the signal at each crossed interface is used to form the image point by point.
If air is founded, the reflected signal is inverted which is traduced by a red or a yellow point on the image.

Interpretation:
All red or yellow area is an area which was interpreted as delaminated by the computer algorithm: this is true in the most of case. However, combination of material or structure (fiber, particle…) can induce the same red image without delamination
This acoustic image in phase inversion must be studied with the acoustic operator comments and not as an absolute information

5.2 Equipment

SONIX Acoustic microscope
Soft SONIX IC LAB/IC PRO Version 4.0 Release 4.01.
Transducter: 75MHz

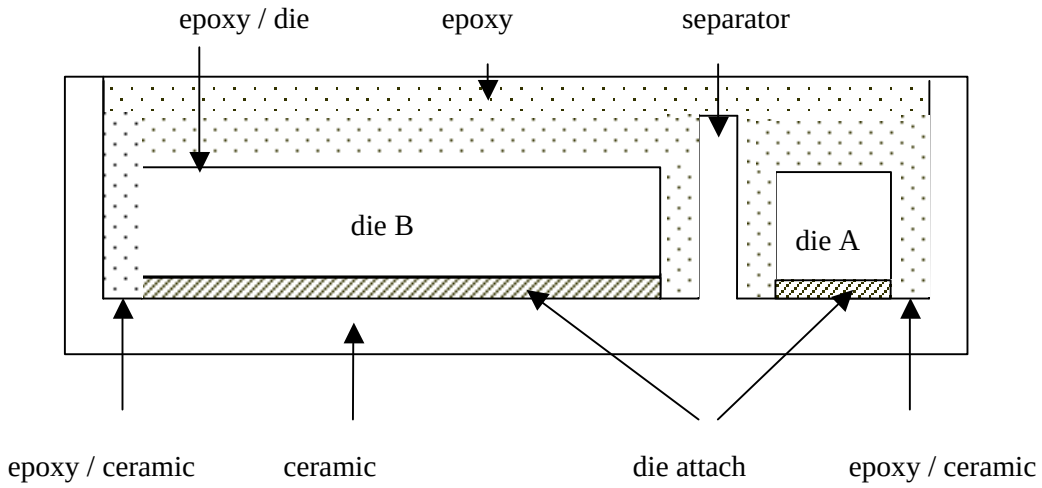
Acoustic microscopy analysis can detect delaminations at various interfaces:
- Epoxy/die
- Epoxy/ceramic
- Epoxy/bonding area (see figure 3)

Procedures and references:

IPC/JEDEC J-STD-035
Acoustic microscopy for non hermetic encapsulated electronics components.

Instruction SERMA Technologies:
ILAB0333 du 18/09/2000; Analyse par microscopie acoustique.

Interfaces location:



5.3 Results synthesis

All the parts were observed at reception and after the 40 thermal cycles for 5 of them.

All along the tests performed, no delamination was detected at die /epoxy interface on the two lots.

The DPDs serial numbers and the figures numbers are detailed on the 3 next pages for each lot. All the figures are given in annex.

Note:

Acoustic analysis was performed top scanning, focus at epoxy/die and epoxy/ceramic interface. Delaminated areas are outlined in red or yellow, however, some red areas on separator or die were not delamination but signal perturbation due to very thin and irregular epoxy layer.

- LOT H1

Beginning of delamination or only delaminated points at epoxy/ceramic interface were observed on 7 parts out of 10 were observed.

- LOT H2 (2D):

Beginning of delamination was observed at epoxy/ceramic interface on 3 parts out of 10 .
Partial delamination at epoxy/ bonding area was detected on 1 part out of 10.

After the 40 additional thermal cycles, a small increase of delamination at epoxy/ceramic interface was observed on 3 parts, there is no evolution on the 2 others:

There is no significant difference between the sub-lot H2C1 and H2C2 at initial and after 40 cycles.

5.4 Lot H1 results

		SERIAL NUMBERS									
		1	2	2	4	5	6	7	8	9	10
	DELAMINATION	H1C1					H1C2				
T_0	Epoxy/die										
	Epoxy/ceramic		B Fig 1	B Fig 1	B Fig 1	B Fig 1	B Fig 1	B Fig 1			B Fig 1
	Epoxy/ bonding area										

B : Beginning of delamination
P : Partial delamination

5.5 Lot H 2 results

		SERIAL NUMBERS									
		737	738	739	740	741	742	743	744	745	746
	DELAMINATION	H2C1					H2C2				
T_0	Epoxy/die										
	Epoxy/ceramic						B Fig 2	B Fig 2			B Fig 2
	Epoxy/ bonding area									P Fig 2	

B : Beginning of delamination
P : Partial delamination

5.6 Lot H2 results (after 40 thermal cycles)

		SERIAL NUMBERS									
			738			741	742		744		746
	DELAMINATION	H2C1					H2C2				
T_1	Epoxy/die										
	Epoxy/ceramic		B Fig 3				P Fig 3				P Fig 3
	Epoxy/ bonding area										

B : Beginning of delamination
P : Partial delamination

5.7 Weighting results (before and after acoustic microscopy)

The weight of the parts was controlled before and after acoustic microscopy. There is no significant weight difference on the components before and after acoustic microscopy.

Weight (g +/- 10 µg) of the DPDs before (at the arrival at SERMA Technologies) and after the acoustic microscopy (immersed in water during about 15 mn).

DPD #	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**mean**
before	1,50892	1,52915	1,53875	1,52338	1,54351	1,53677	1,58003	1,57209	1,59529	1,51527	1,54754
after	1,50901	1,52936	1,53884	1,52345	1,54364	1,53688	1,58024	1,57232	1,59541	1,51547	1,54768
DPD #	**737**	**738**	**739**	**740**	**741**	**742**	**743**	**744**	**745**	**746**	**mean**
before	1,55103	1,53411	1,53033	1,50818	1,56024	1,53357	1,52437	1,55486	1,55740	1,49751	1,53934
after	1,55127	1,53431	1,53046	1,50838	1,56038	1,53376	1,52458	1,55498	1,55757	1,49771	1,53952

We measure a mean increase of the DPD weight of 14µg for lot H1 and 18 µg for lot H2, so the acoustic test for relatively wet DPD do not change a lot its weight.

Notice

The analysis of the weight difference between the present lots and the previous lots (DR1 & DR2) shows that the present lots have a lower weight.
In addition, taking in account that the ceramic and die have a constant weight (measured around 1.395 g in previous analysis DR3) the estimated weight of epoxy resin for these 2 lots is around 0.15g.

On the present lots, the weight of epoxy resin is 38% lower than the previous lots (0.15 g versus 0.24 g estimated in previous analysis DR3).

6. ELECTRICAL MEASUREMENT

6.1 Measurement performed

The direct breakdown voltage of each diode (VF / If) in dark environment was controlled at reception at temperature ambient and after acoustic microscopy and thermal cycles from 60°C to –30°C.

During the ramp of temperature, the control was done on Go/noGo basis, the ramp of temperature was 10°C / minute, the control was performed every 10°C.

A parameter Analyser HP 4155 and a FROILABO Dragon temperature forcing system were used to perform the control.

6.2 Results synthesis

All along the tests performed, no electrical defect was detected.

The results (graph) obtained on one part of each at room ambient and –30°C are given in annex.

7. S.E.M. INSPECTION

7.1 Purpose

The purpose of this analysis was to inspect the wire bonding of samples which present delamination at bonding area or lost of electrical contact in order to verify if the defect observed on a previous analysis E02P1100 (a thinning of wire bonding was detected on one functional part)

The same method was used to remove the epoxy resin : partial chemical attack of protective coating above the dice .

Two parts were concerned for this analysis : S/N 9 from lot H1 and S/N 745 from lot H2

7.2 Results

No degradation of the wire bonding was evidenced.

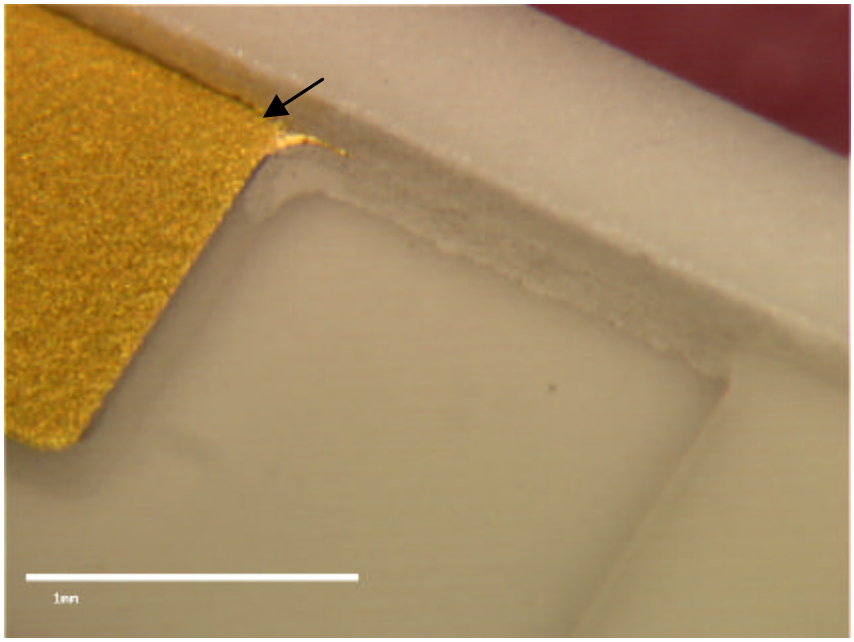
The wire bonding thinning observed on the previous analysis (DR3) was not present on these parts.

8. ANNEX 1 : INSPECTION at RECEPTION

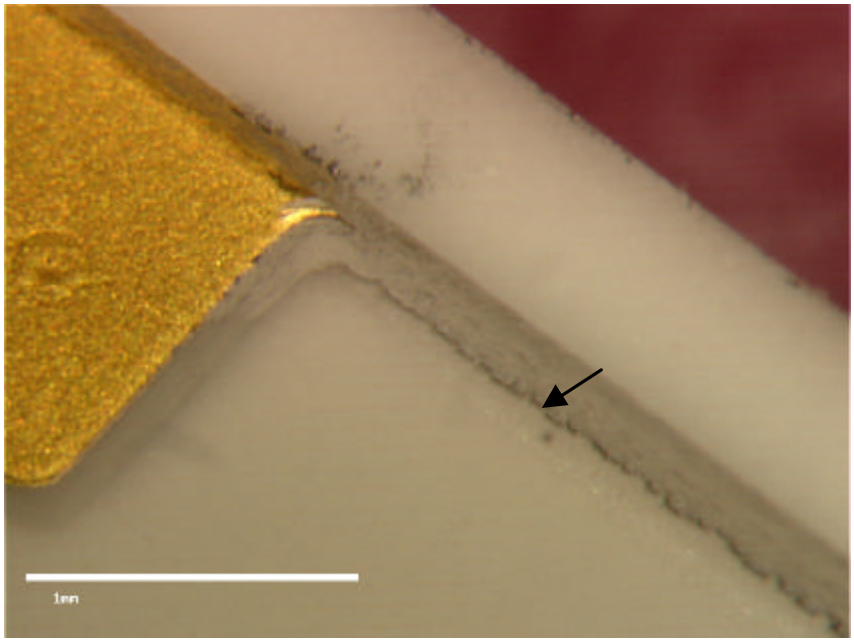
- Bags and boxes views : Figures I1 to I3

9. ANNEX 2 : VISUAL INSPECTION FIGURES

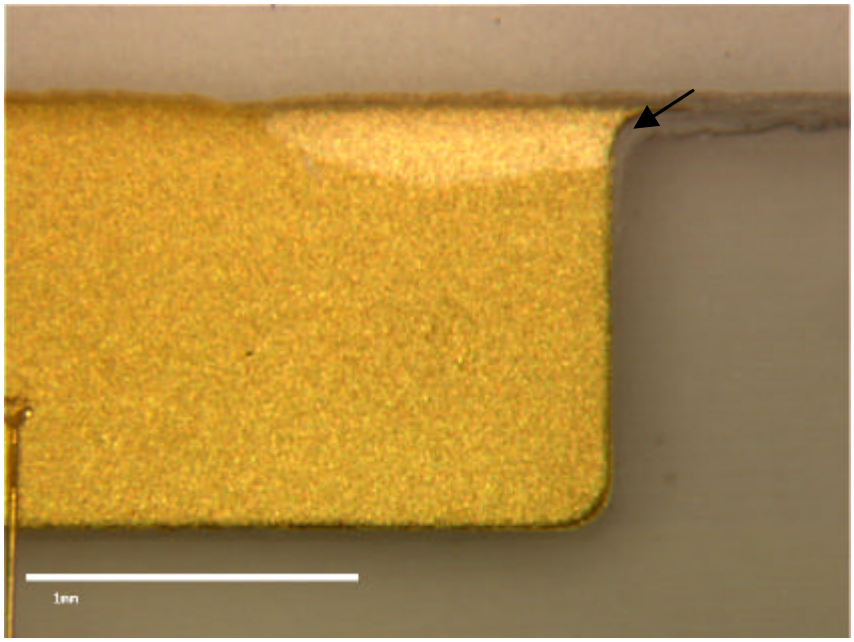
- LOT H1 : Figure 1
- LOT H2 : Figure 2
- LOT H2 after 40 cycles : Figure 3



S/N 3

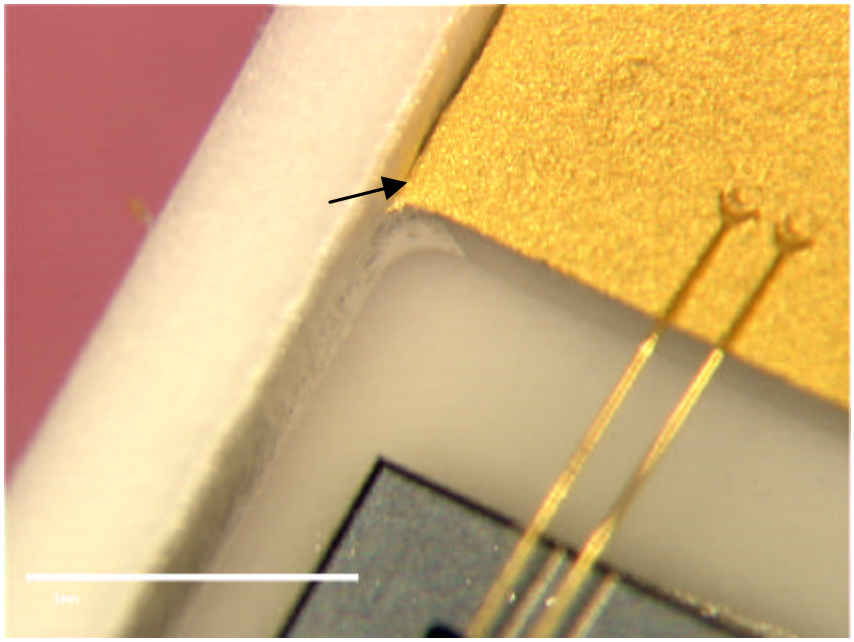


S/N 9

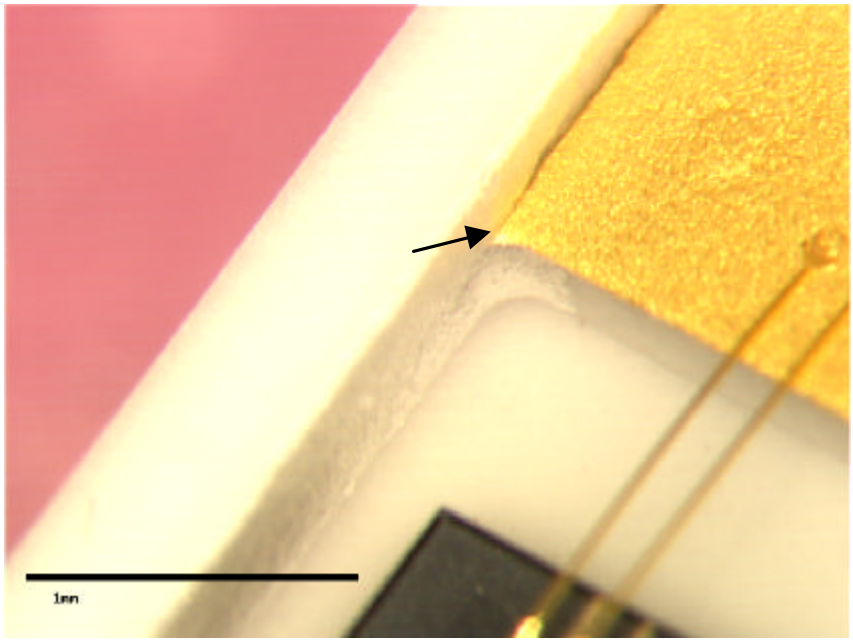


S/N 7

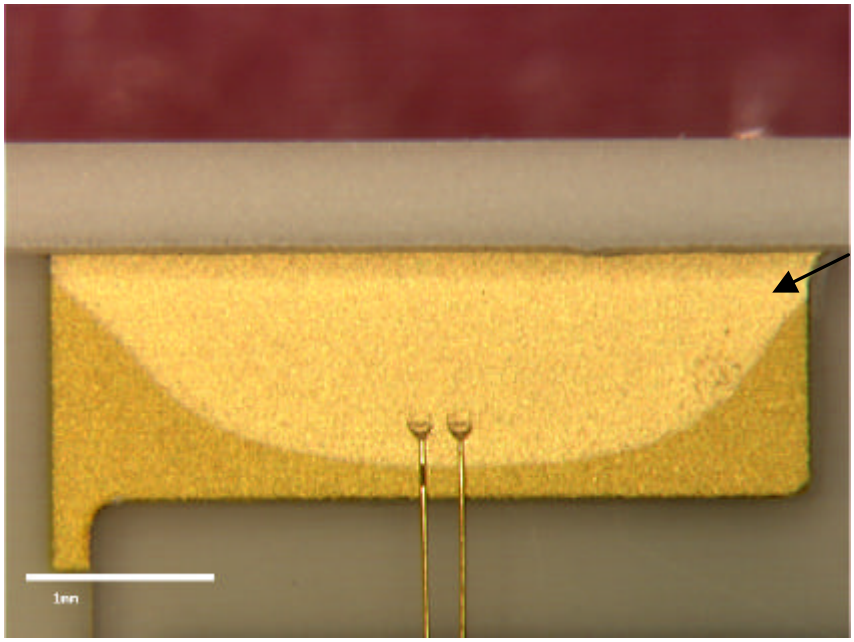
Figure 1. Details of delamination at epoxy/ceramic and epoxy/bonding area at T0, Lot H1.



S/N 743

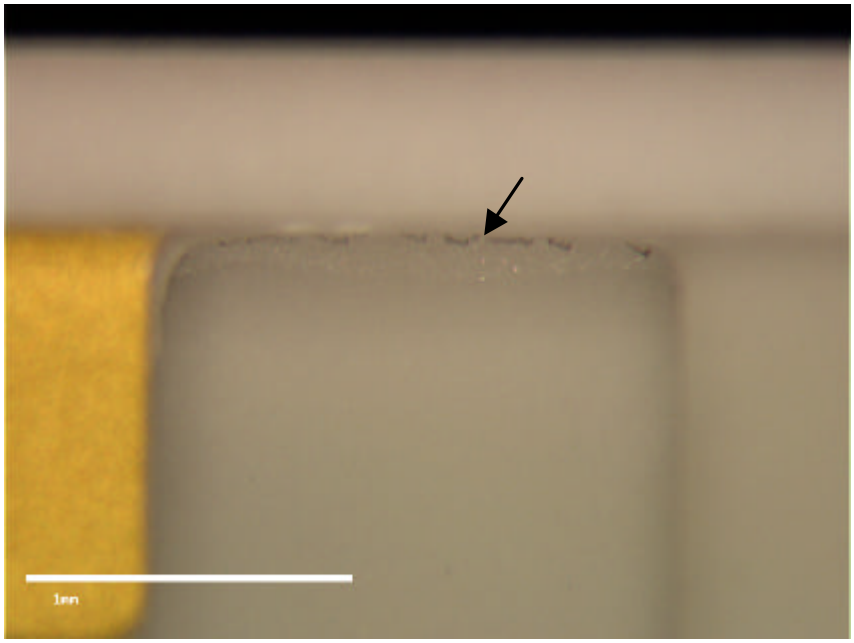


S/N 746

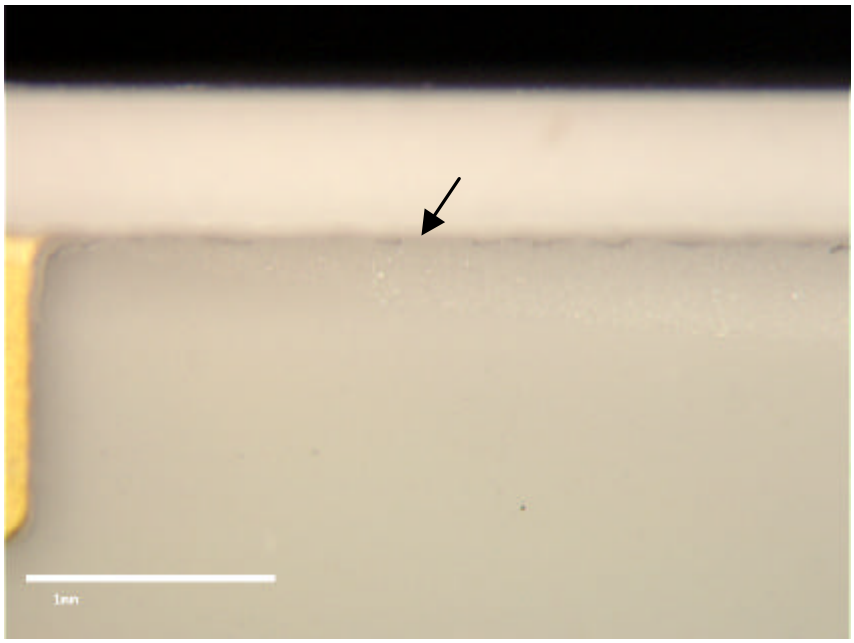


S/N 745

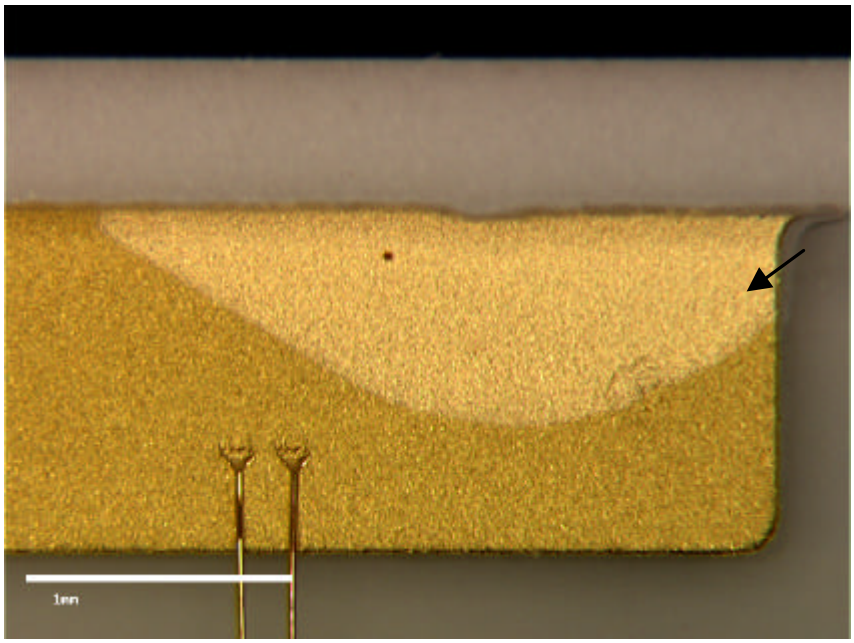
Figure 2. Details of delamination at epoxy/ceramic and epoxy/bonding area at T0, Lot H2.



S/N 742



S/N 746



S/N 742

Figure 3. Details of delamination at epoxy/ceramic and epoxy/bonding area, Lot H2 after 40 cycles.

10. ANNEX 3 : ACOUSTIC MICROSCOPY FIGURES

- LOT H1 : Figure 1
- LOT H2 : Figure 2
- LOT H2 after 40 cycles : Figure 3

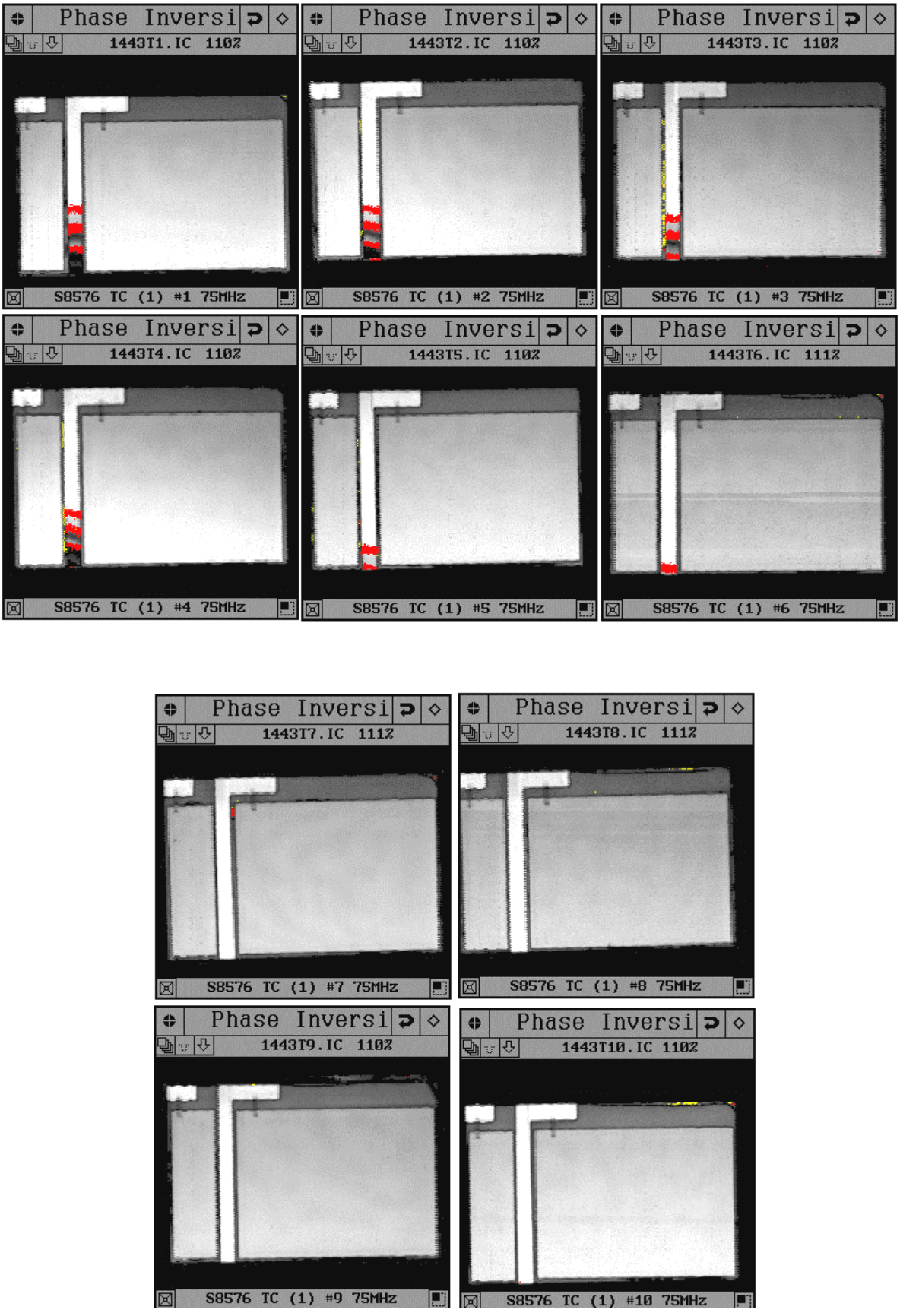


Figure 1. Acoustic microscopy, delamination images.
Epoxy/die and epoxy/ceramic interfaces.
Lot H1 (Parts 1 to 10) ; T_0.

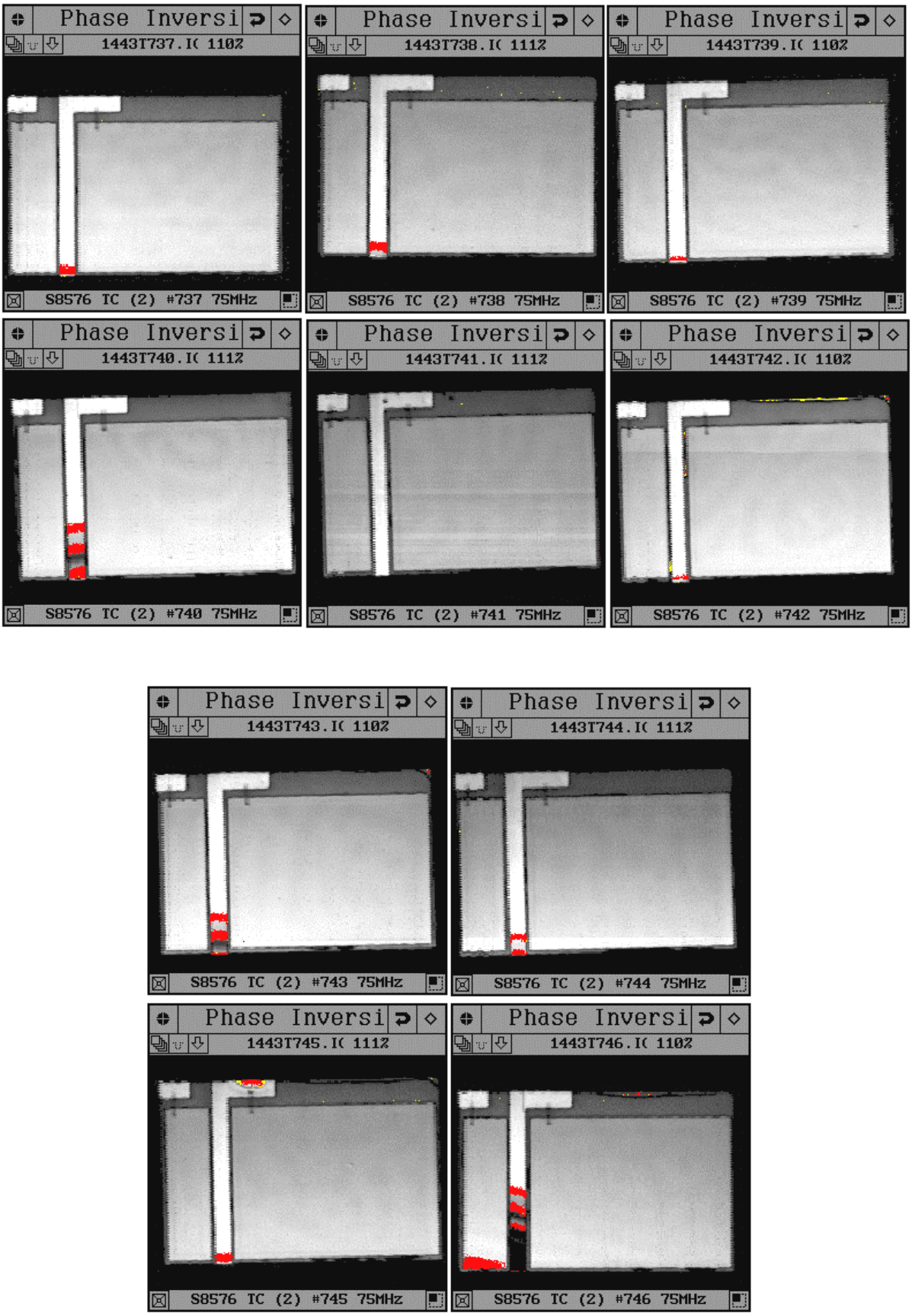


Figure 2. Acoustic microscopy, delamination images.
Epoxy/die and epoxy/ceramic interfaces.
Lot H2 (Parts 737 to 746) ; T_0.

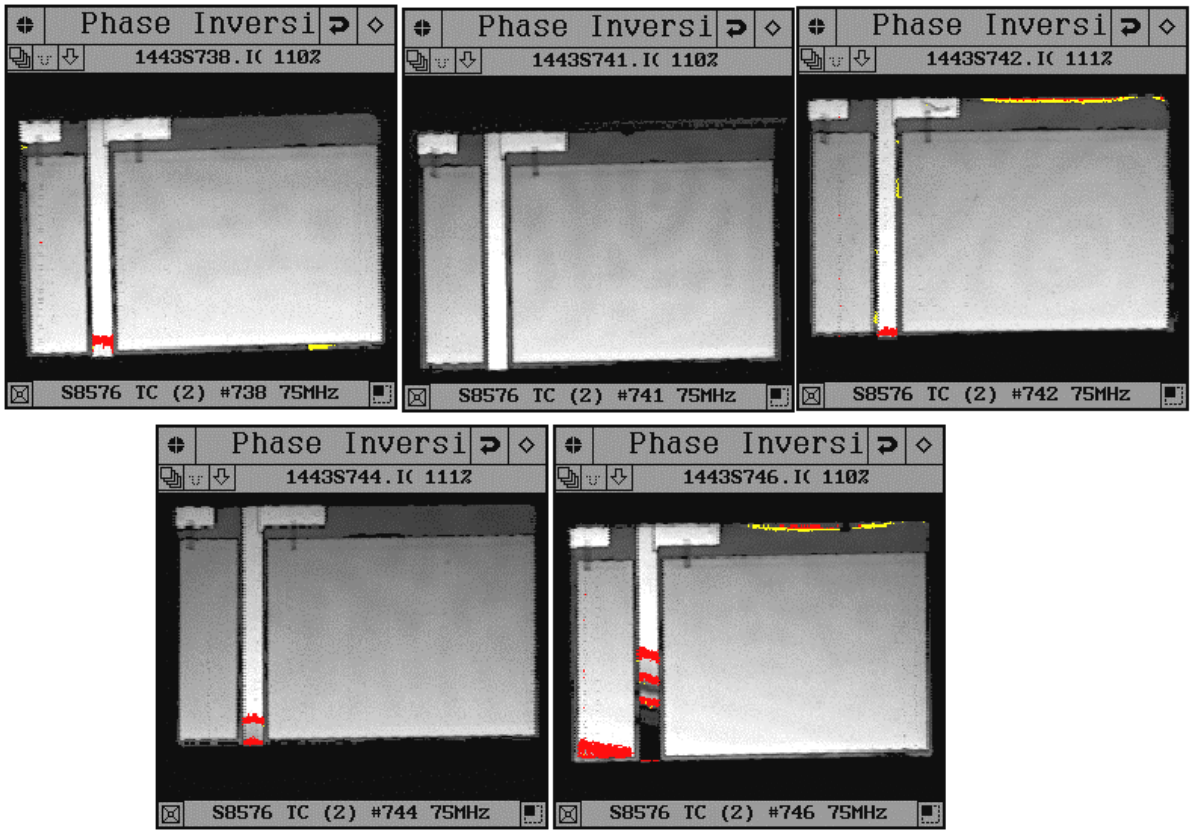
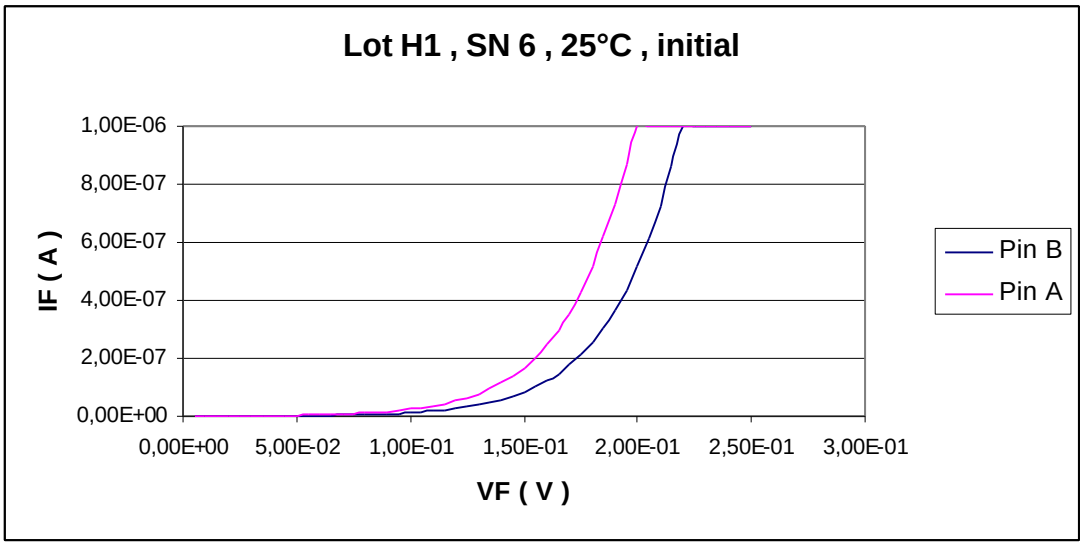


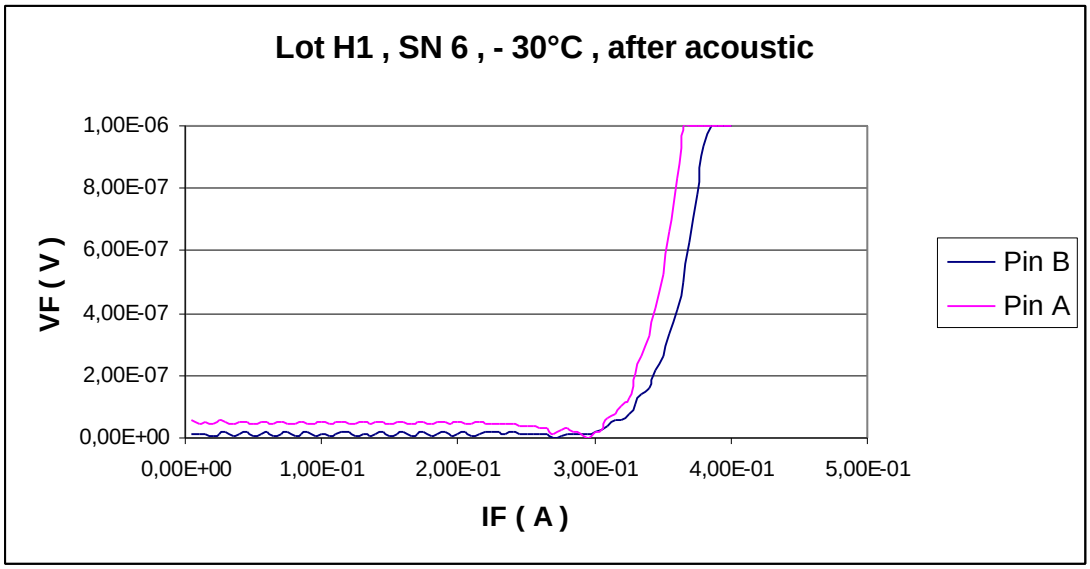
Figure 3. Acoustic microscopy, delamination images.
Epoxy/die and epoxy/ceramic interfaces.
Lot H2 (Parts 738,741,742,744 and 746) ; T_1.

11. ANNEX 4 : ELECTRICAL TEST GRAPHS

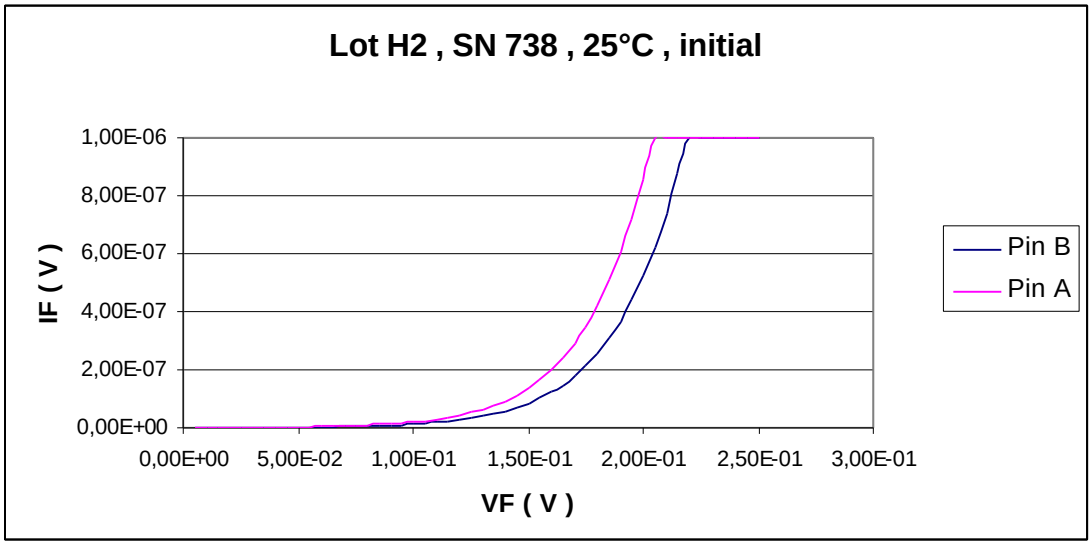
- LOT H1 : S/N 6
- LOT H2 : S/N 738

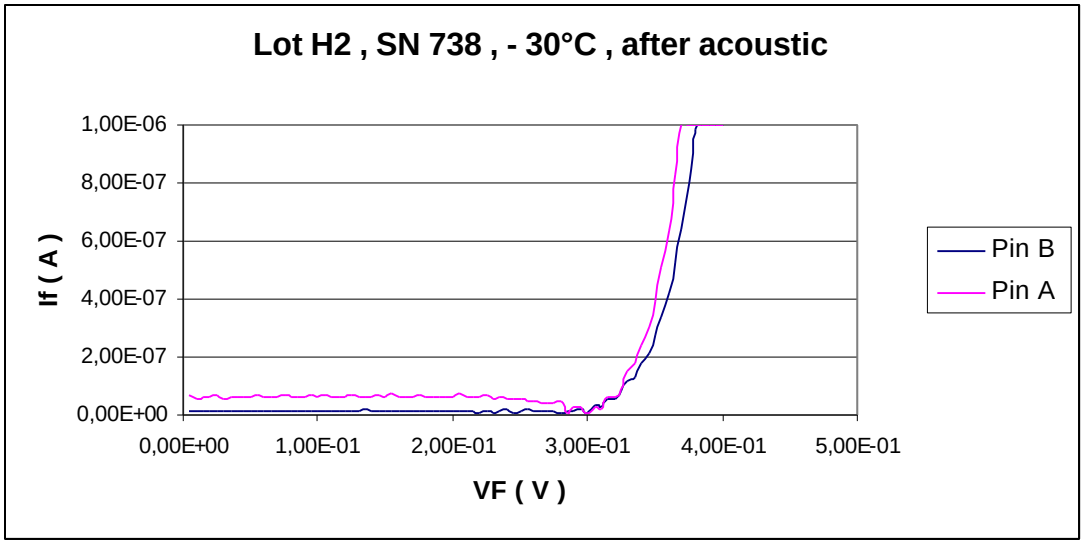
11.1 Lot H1 S/N 6 results

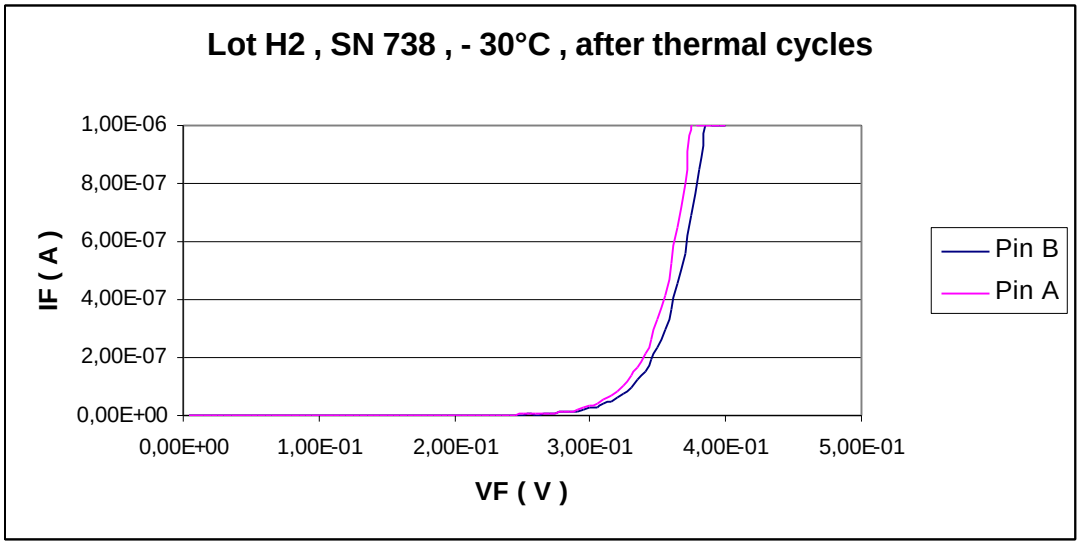




11.2 Lot H2 S/N 738 results

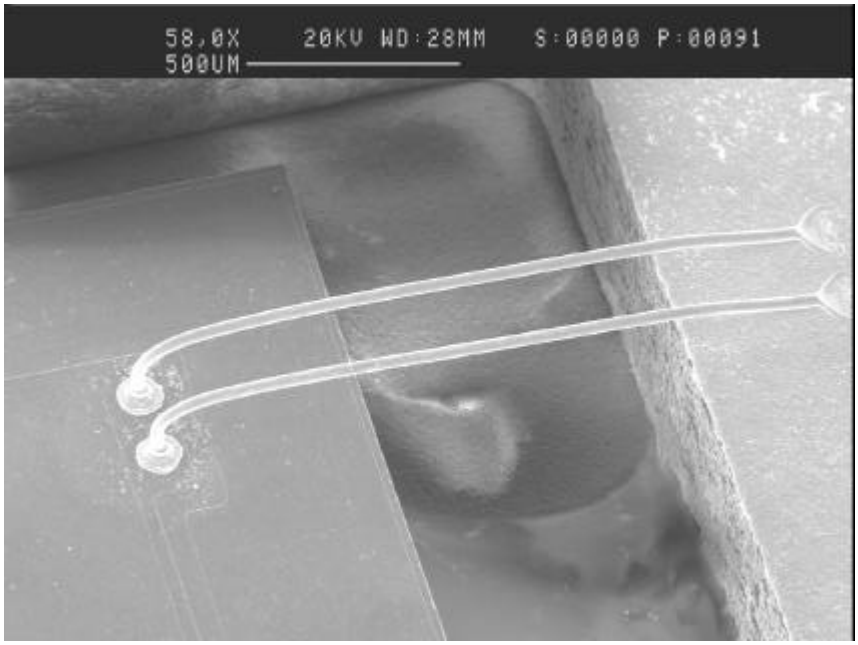






12. ANNEX 5 : S.E.M INSPECTION

- SEM views : Figures 1 to 3



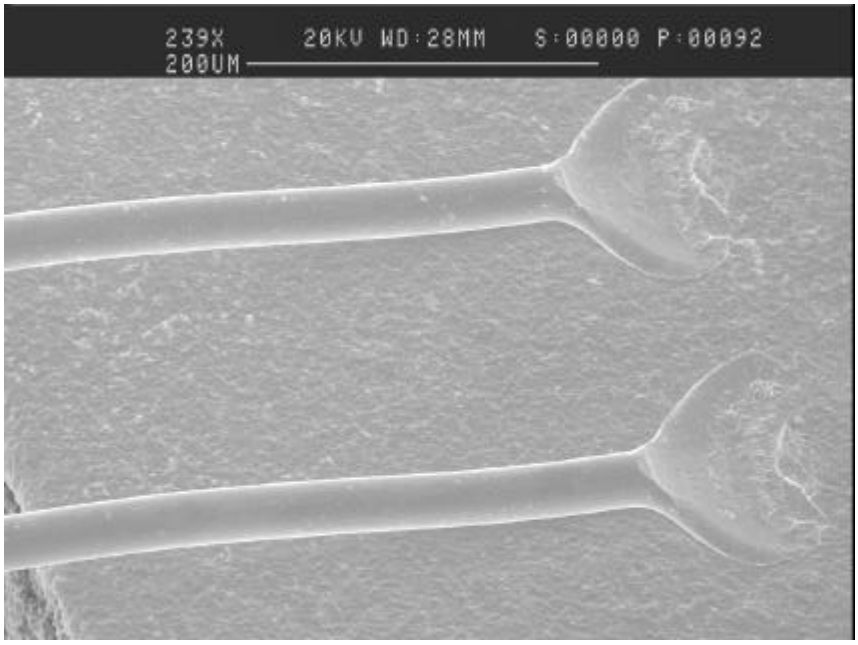
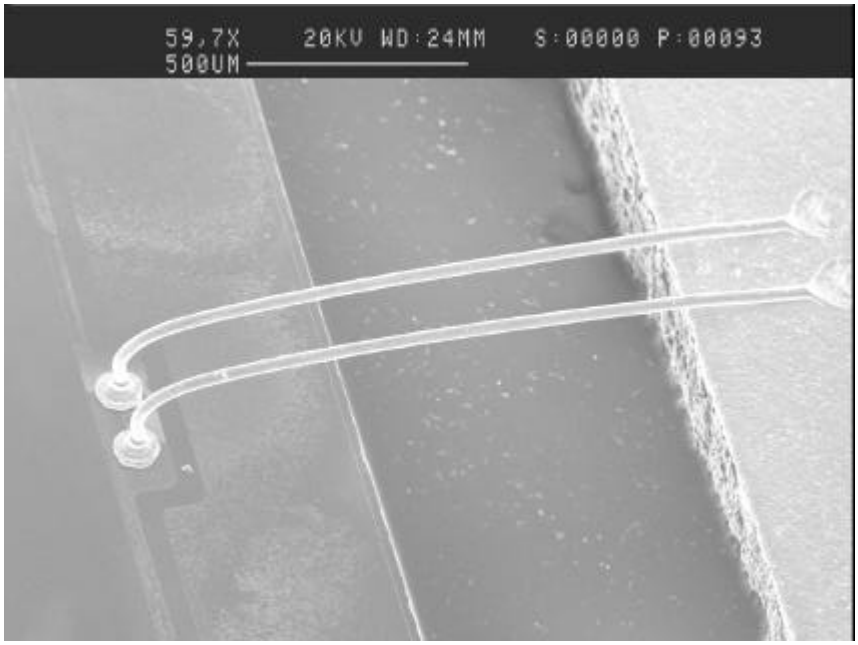


Figure 1. SEM views of the wire bonding, Pin A, # 9.
Top : mag 58X ; bottom : mag 239X.



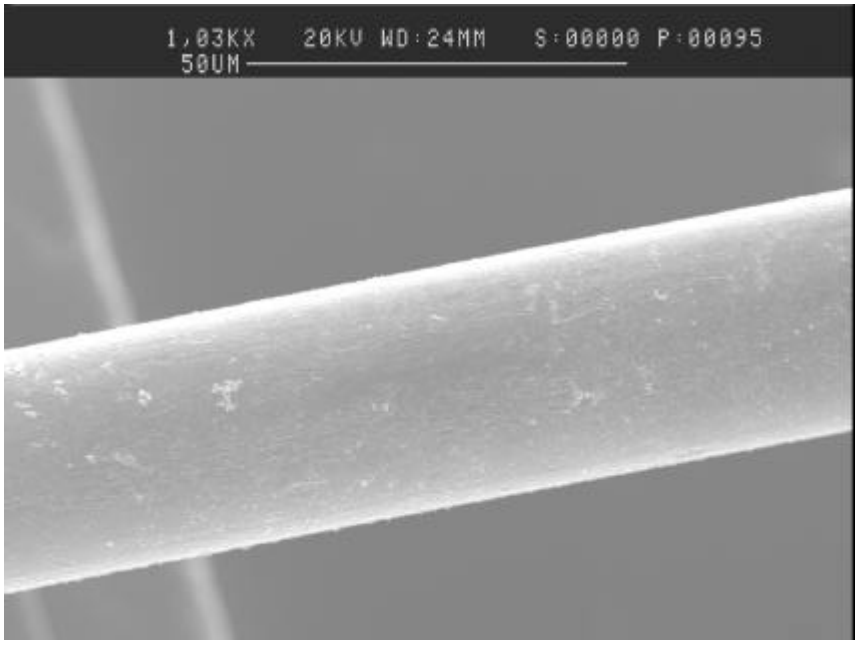


Figure 2. SEM views of the wire bondings, Pin B, # 9.
Top : mag 60X ; bottom : mag 1030X.

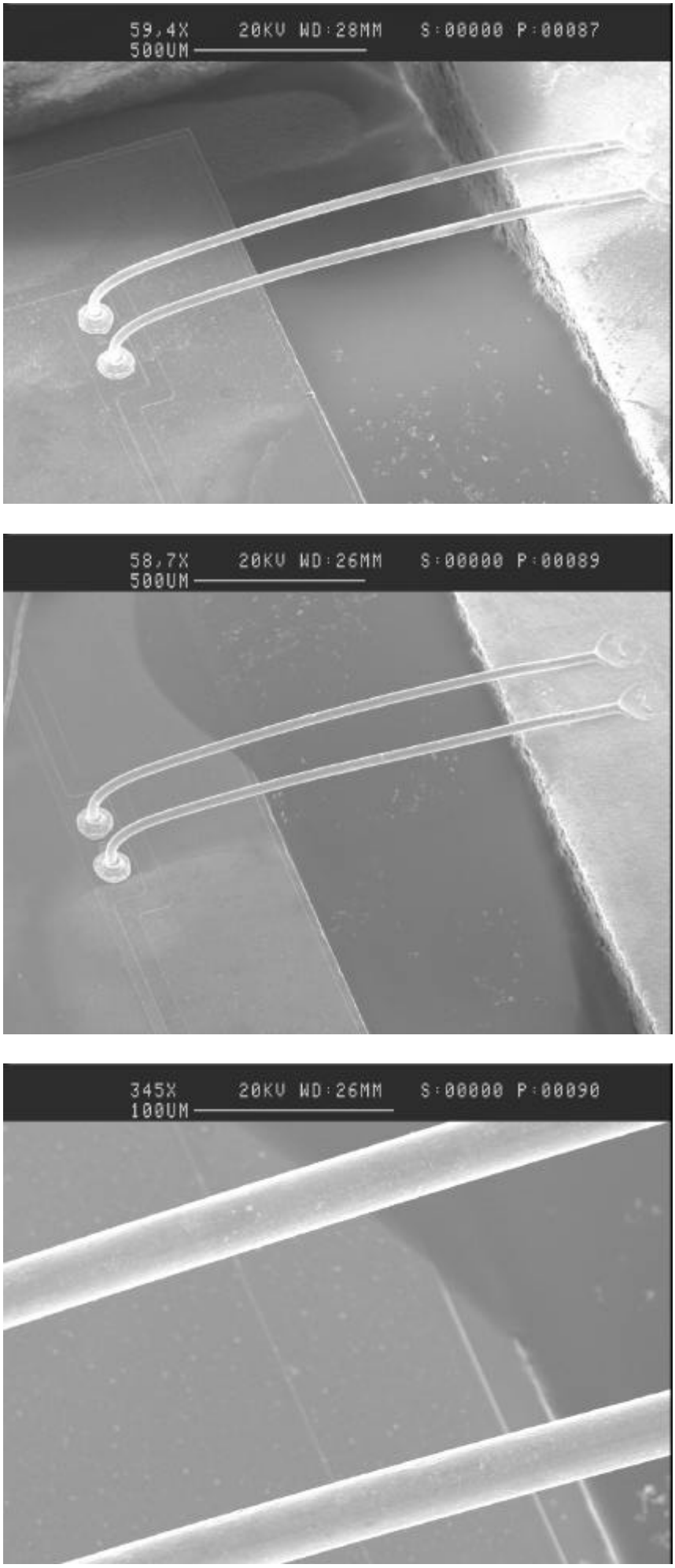


Figure 3. SEM views of the wire bondings, Pin A and Pin B, # 0745.
Top and center : mag 59X ; bottom : mag 345X.